

# CONTROL UNIT FOR CONTROLLING SAFETY-CRITICAL APPLICATIONS

The present invention relates to a control unit for controlling safety-critical applications, having a microcomputer (MC), a monitoring unit (check unit, CU), and peripheral circuits (input output, IO). Furthermore, the present invention relates to a method for checking a microcomputer (MC) of a control unit for controlling safety-critical applications, the control unit having microcomputer (MC), a monitoring unit (check unit, CU), and peripheral circuits (input output, IO).

## Background Information

In control units that control or regulate applications or functions that are critical with regard to safety, errors of the microcomputer (MC) or of a processor of the microcomputer must be detected by monitoring. Such control units having safety tasks are used, for example, for anti-lock braking systems, for traction control systems, and/or for electronic stability programs. The safety-critical applications controlled by the control unit are connected to the control unit via the peripheral circuits. In the case of single-computer control units, methods having a self-test, plausibility check, and watchdog are known.

For testing CMOS chips (integrated circuits, IC) at the manufacturer, methods and measuring devices for measuring the quiescent current are used. The background of the so-called quiescent current test is that in a digital CMOS chip in

purely static logic, almost the entire power loss during the switching operations occurs in its interior. In the rest state, the current flow is restricted to tiny leakage currents as well as to currents through pullup resistors or pulldown resistors at the inputs and through external loads at the output drivers. Many production-dependent errors lead to increased conductivity between the positive and negative supply voltage. Activating such defective regions (point defects) of the circuit causes the current consumption to increase abruptly. Such defects can be ascertained by a highly exact measurement of the current consumption during the test operation and a comparison to corresponding setpoint values. As already stated, such a quiescent current measurement is used in the manufacture of CMOS chips to sort out the defective chips after the manufacturing process.

It is known from the related art to also use the quiescent current test method known in the manufacture of computer modules for control units of the species cited at the outset to test the computer modules during their normal operation in order to be able to detect the most frequent defects in the computer modules, in particular in the microcomputer (MC), e.g. lock-up errors (stuck-at), bridge errors (bridging), and/or interrupt errors (stuck-open).

It is further known from the related art to provide two MCs, which reciprocally test one another by parallel computing and/or plausibility checks, to increase reliability in the case of control units of the species cited at the outset. However, cost considerations result in the suggestion of using only one MC for such control units.

The object of the present invention is to develop and further

refine a control unit of the species cited at the outset to the effect that the reliability of the error detection is further improved, and the detection is expanded to additional types of errors.

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To achieve this object, starting from a control unit of the species cited at the outset, the present invention proposes that the monitoring unit (CU) has first means for measuring the quiescent current of the microcomputer (MC), that at least one handshake line for controlling the measurement of the quiescent current runs between the first means of the CU and the MC, that the CU has second means for applying a test data input signal to the MC to process the test data input signal and compare the corresponding test data output signal of the MC to the corresponding test data output signal of the CU, and that at least one test data signal transmission line runs between the second means of the CU and the MC.

In accordance with the present invention, it was recognized that the reliability of the error detection can be increased by using two different test methods that supplement one another. In this manner, a significantly greater number of different error types of the computer modules of the MC can be detected.

The control unit according to the present invention can also have a plurality of MCs and a plurality of CUs. However, the following assumes that the control unit has one MC and one CU. The CU of the control unit according to the present invention has a first means for measuring the quiescent current of the MC.

At least one handshake line for controlling the measurement of

the quiescent current runs between the first means of the CU and the MC. The handshake line can, for example, be designed as a bidirectional line.

5 After the control unit is switched on, the quiescent current is measured for a set number (typically 8 to 16) of selected commands within the framework of a test program. For example, 14 selected commands containing an internal machine cycle are processed for microcomputer TMS470.

10 To supplement the quiescent current measurement, the CU of the control unit according to the present invention has a second means. At least one transmission line for test data signals runs between the second means of the CU and the MC.

15 The second means apply a test data signal to the MC. The MC calculates a test data output signal, which is dependent upon the test data input signal and the states inside the MC. Defective states result in a changed test data output signal  
20 of the MC.

25 In the second means of the CU, the test data input signal is also processed to form a test data output signal that is used as a reference signal for checking the test data output signal of the MC. When calculating the test data output signal, the CU assumes an error-free, functioning MC. The completed calculation preferably has a very simple design. The microcomputer does not have a double design, and the same computation is not carried out by the CU as by the MC, as is  
30 the case for parallel computer systems. Rather, starting from the input data of a predefined test function, the MC calculates the output data whose results are checked by the CU using the reference signal calculated by it. The test function

used for calculating the output data typically has a very simple design. The calculation only requires minimal computing time. However, complex tests and results from the application programs can also be included in this test function.

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Finally, the test data output signal of the CU is compared to the test data output signal of the MC. If they deviate from one another, or if the deviation exceeds a predetermined threshold value, the CU recognizes an error of the MC. The test result can be displayed by a display device and/or it can be provided that upon occurrence of an error, provision is made for the system controlled and/or regulated by the control unit to be switched off.

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According to an advantageous further refinement of the present invention, it is proposed that the first means include an IDDQ measuring circuit, a voltage supply, an IDDQ measuring run control (MAS), and a control system of the CU, and that the connection between the first means and the MC includes two handshake lines that run from the IDDQ-MAS to the MC and at least one voltage supply line that runs from the voltage supply to the MC, at least one of the voltage supply lines running through {or across} the IDDQ measuring circuit. In semiconductors, IDD designates the positive supply current. IDDQ designates the quiescent current. The handshake lines are, for example, configured as START and END handshake lines for starting and acknowledging the completion of the functional test.

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The communication between the MC and the CU for measuring the quiescent current is carried out via the two handshake lines. The quiescent current of the MC is measured by the CU via the separate voltage supply lines.

As stated, the present invention relates to a control unit having a monitoring unit for checking the microcomputer of the control unit. A voltage supply unit is provided for supplying voltage to the control unit and, as such, also to the  
5 microcomputer. The control unit of the CU includes means that can bring the MC into specific operating states. Furthermore, present in the IDDQ measuring circuit are measuring means that ascertain the current or voltage in the voltage supply circuit of the MC, whereupon the determined current or the determined  
10 voltage is compared in comparison means, also present in the IDDQ measuring circuit, to at least one predefined threshold value.

By simply measuring the current or voltage, a plurality of  
5 possible errors in the computer can be ascertained using the IDDQ measurement. In this context, the most frequent errors in the components of the MC can be substantially covered using a minimum of test steps. Such errors can be lock-up errors (stuck-at), bridge errors (bridging), and/or interrupt errors  
20 (stuck-open).

As a result of the combination of the quiescent current measurement and another suitable checking method, in particular including a check of the functionality of the MC  
25 based on test data records, errors are widely covered with respect to the significant errors in computer modules, in particular in CMOS processors, in a manner particularly advantageous for safety-critical applications.

30 The abovementioned elimination of the second processor is largely retained as an economic advantage of the control unit according to the present invention, since the quiescent current measurement according to the present invention only

requires a minimal hardware expenditure.

By specially controlling the MC, the IDDQ-MAS brings predetermined components of the MC into a low-current state.

5 The background of this control is that typically components are present in the MC that require a relatively high current. Since, as stated at the outset, the quiescent current measurement is generally based on fluctuations in the quiescent current within relatively small bandwidths, the high  
10 current consumption of the MC components interfere with the IDDQ measurement. In particular, it is provided that components to which the IDDQ measurement does not apply are brought into a low-current state. Such components can be the MC output stage and/or an input stage (e.g. analog/digital converter) as well as circuits for internally multiplying the clock pulse. In the simplest case, the components having high current consumption are switched off during the test. Thus, internal circuit elements and circuit outputs that carry high currents are switched off. Subsequently, the quiescent current  
20 can be measured.

In addition to switching off the components of the MC having high current as mentioned above, it can also be provided that the core of the MC is to be brought into a state of low  
25 current consumption. In the case of such MC modules configured specifically for the quiescent current measurement, a special operating state, a so-called IDDQ test mode, is provided. In this operating state, all currents inside of the computer are switched off, i.e., the current in the MC core is minimized.  
30 The IDDQ design is such that standard errors in the MC core become noticeable as an increase in the quiescent current. Thus, for example, short-circuit errors and/or stuck-at errors (short circuit to ground or the supply voltage) are

immediately manifested in an increase in the quiescent current. In this context, it is not necessary to pass on (to propagate) the effect of such an error to the outputs of the MC. The increased current consumption is the immediate error indicator.

In addition to the IDDQ test mode described above, it can be provided that only the MC components having a high current are switched off, and, in response to a command, the MC enters a defined low-current state. In this context, the MC core does not have to be specially configured for the IDDQ test mode. This is called the power-down mode.

The power-down mode is initiated by loading internal components of the computer, such as the register and memory, with certain patterns, and by bringing the abovementioned computer components into a state of low current consumption, e.g. by executing a certain computer command. If this state is achieved, a clock generator can be selectively switched off or disconnected. Subsequently, the quiescent current or a corresponding voltage value is measured and compared to a threshold value corresponding to the above-set operating state (power-down state) of the MC core . If certain errors are present in the computer (stuck-at errors, bridging errors, stuck-open errors), the result is typically an increase in the quiescent current or in the voltage drop caused by the quiescent current.

After such a test step, additional test steps can follow in that the power-down mode is first exited by applying certain signal levels to specific connections of the MC. By again starting or switching on the clock generator, the internal computer components, such as the register and the memory, are



loaded with additional patterns, and the abovementioned components are again brought into a low-current state, e.g. by executing a specific computer command (power-down command). The above-described measurement of the quiescent current then follows. As a result of a plurality of such consecutively performed measurements of the power-down current, errors in the registers, memories, and components of the computer core are ascertained in an increasingly more complete manner.

According to the computer type and design of the circuit, the individual test steps are ended by re-enabling the clock generator, by triggering a reset, or by triggering an external interrupt. After the last test step, the MC runs again in its normal operating mode (normal operation).

In addition of the above-described quiescent current measurement in the power-down mode, provision is also made in accordance with the present invention for the quiescent current to be measured in the indicated IDDQ test mode, provided the computer to be checked is suitably configured. The start of the IDDQ test mode is initiated by changing the signal level at a connection of the MC, for example. Also in this context, the register and memory are loaded with certain patterns prior to entering the IDDQ test mode. Upon entering the IDDQ test mode, the computer components having high current consumption are switched off. Furthermore, by discontinuing or decoupling the time pulse while executing a command, the computer core can be kept in a state typical for this command. These commands are selected in such a manner that they adjust the states of the internal circuit nodes of the computer core so that as many errors as possible can be detected via the quiescent current measurement.

The handshake for the quiescent current measurement is carried out in a number of steps:

5 S1: The MC sets the START signal to HIGH. Consequently, the CU knows that an IDDQ measurement is beginning.

S2: The MC can selectively prepare to stop the time pulse (master clock, MCLK), in that it sets a signal PREP to LOW via an internal command.

10 S3: The MC decodes the precisely defined instant within the next suitable command for the IDDQ test and also sets a signal DEKOD to LOW. Now the MCLK is set equal to LOW, and the digital component of the MC is set to static operation for the IDDQ measurement.

S4: The CU performs the IDDQ measurement.

15 S5: The CU outputs the level sequence LOW-HIGH-LOW at the signal END, thereby reactivating the MCLK.

20 S6: The MC becomes active again and confirms the end of the measurement by setting the START signal to LOW. The MC continues the program and prepares the next IDDQ measurement or ends the IDDQ measurement when all measurements have been carried out.

25 Two voltage supply lines preferably run between the voltage supply and the MC, one voltage supply line running through the IDDQ measuring circuit. The quiescent current of the MC is measured via the voltage supply line that runs through the IDDQ measuring circuit.

30 According to another advantageous further refinement of the control unit according to the present invention, it is proposed that the first means include an IDDQ measuring circuit, a voltage supply, an IDDQ measuring run control (MAS), and a control system of the CU, and that the connection

between the first means and the MC includes four handshake lines that run from the IDDQ-MAS to the MC and at least one voltage supply line that runs from the voltage supply to the MC, at least one of the voltage supply lines running through the IDDQ measuring circuit. In the case of four handshake lines, a time-pulse (CLK) line and a line for a power-down (PWRDN) control can be provided for the MC in addition to the lines START, END in the case of two handshake lines. In this specific embodiment of the control unit, a shared voltage supply line to the processor is sufficient, the quiescent current being measured in the voltage supply line. The clock generator is then stopped in the CU. The control of voltage supply circuits for analog circuits and IO circuits in the MC is carried out via the PWRDN line from the CU. As such, only the quiescent current of the digital component of the MC flows in the measuring case through the shared voltage supply line.

Advantageously, the first means have an initialization circuit, which receives an initialization signal from the voltage supply after the control unit is switched on and subsequently transmits an enable signal to the IDDQ-MAS to enable the IDDQ measurement. The successful completion of the IDDQ measurement is signaled by an additional signal to the control system of the CU. Consequently, the CU advances the test run in that the initialization circuit enables the test data signal generator via an additional signal.

According to an advantageous specific embodiment of the present invention, the second means include a test data signal generator for applying a test data input signal to the MC, a response generator for processing the test data input signal and for forming a corresponding test data output signal, a test data register for transmitting and receiving test data,

and a comparator for comparing the test data output signal of the MC to the test data output signal of the CU; and the connection between the second means and the MC includes at least one test data transmission line, which runs between the test data register and the MC. Advantageously, two test data transmission lines run between the test data register and the MC.

The test data signal generator is also activated by the initialization circuit after the control unit is enabled. In the test data signal generator, the test data for the MC are generated in a virtually random order by a feedback shift register. With the aid of the Reed-Muller codes, the bit string for the test data output signal (the so-called reference signal) is formed in the response generator, for every test data input signal. This code is used to maintain a distance that is as great as possible in the space of numbers of the test data output signals (hamming distance). In the comparator, the theoretically calculated test data output signal from the response generator of the CU is then compared to the actual test data output signal of the MC from the test data register.

The second means preferably have a trigger generator, which determines the instant at which the test data output signal of the MC is available at the comparator, in the case of an error-free MC. The trigger generator stipulates the instant of the comparison of the determined test data output signal of the MC and the actual response of the CU. As a result, it is ensure that the time slices in the MC proceed correctly. The comparator not only checks the test data output signal for the correct data value but also to determine whether the test data output signal is transmitted within a specific timing window.

Advantageously, the second means have a error counter, which counts up or down, in the event that the test data output signal of the MC is not consistent with the test data output signal of the CU, and/or in the event that the test data output signal of the MC is available at the comparator at an instant that differs from the one determined by the trigger generator. By a counting pulse, the comparator causes the error counter to count up or down. If the value and instant of the test data output signal are correct, the error counter is decremented, for example. If the error counter falls below a predefined value, an external warning light, for example, is switched on or off via a signal interface, and a relay for manipulating the safety-critical application is enabled.

The manipulation of the application to be controlled is typically limited to discontinuing the application. In the case of special applications, it can, however, be useful for the error counter to have a plurality of response thresholds, exceeding the response threshold resulting in a different reaction in each case. As a result, the application can be prevented from being immediately interrupted in the case of a singular disturbance, and the disabling path can be checked by the computer.

If the MC responds to a test data input signal at the wrong instant or with an incorrect value, the same test data input signal is applied to the MC again until the instant and value of the test data output signal are correct. If this does not occur with a predefined time period, the CU switches off the control unit or the application, and it cannot be re-activated even by correct responses.

The second means preferably have an initialization circuit,

which receives an initialization signal from the voltage source after the control unit is enabled, subsequently synchronizes the CU with the MC, and then activates the test data signal generator and the error counter. The CU is  
5 synchronized with the MC in that the CU waits for the first data transmission of the MC.

An additional object of the present invention is to develop and further refine a method for checking a microcomputer of  
10 the species cited at the outset to the effect that the reliability of the error detection are further improved, and the detection is expanded to additional types of errors.

To achieve this object, starting from the method of the species cited at the outset, the present invention proposes  
15 that the CU of the control unit measures the quiescent current of the MC and applies a test data input signal to the MC, determines a first test data output signal, and compares a second test data output signal of the MC to the first test  
20 data output signal of the CU.

Advantageously, the quiescent current measurement is in the form of an IDDQ measurement. Preferably, the IDDQ measurement is carried out after the control unit is switched on after  
25 being enabled by an enable signal.

According to an advantageous further refinement of the method according to the present invention, the second test data output signal of the MC is compared to the first test data  
30 output signal of the CU while the control unit is in operation. This has the advantage that the control unit does not have to be switched off to test the functionality of the microcomputer. Rather, MC computing power not used for

controlling the application can be used to check the MC while the control unit is in operation.

Preferably, a false test data output signal is transmitted one  
5 time at regular intervals to the CU while the control unit is in operation to check the functionality of the disabling path.

An additional advantageous embodiment of the present invention  
10 start from the assumption that a clock generator is stopped by the MC during the IDDQ measurement and/or while the second test data output signal of the MC is being compared to the first test data output signal of the CU. The clock generator is provided in the control system of the CU. The internal  
15 computer operations in particular are controlled as a function of the output signal of this clock generator. In the described IDDQ test mode, it is provided that this clock generator is switched off or disabled or disconnected from the MC. This can also be carried out in the power-down mode when a particularly low quiescent current is to be achieved. The clock generator  
20 is switched off or disabled or disconnected especially at the start of every quiescent current measurement.

Preferably, the test data input signal of the CU is generated  
25 by a test data signal generator, via a feedback shift register. Preferably, the test data output signal of the CU is generated by a response generator, with the aid of the Reed-Muller code.

The control unit according to the present invention can be  
30 checked by two different test runs. A so-called start-up test is carried out immediately following the switching on of the control unit and prior to the operation of the control unit for controlling or regulating the safety-critical application.

After the start-up test, a so-called online test is carried out from time to time while the control unit is in operation.

5 The start-up test is subdivided into two test segments, the so-called processor initialization segment (Proz-Init) and the subsequent so-called operating system initialization segment (BS-Init). The processor initialization segment includes a command test and a core test, a RAM/ROM test, and an IDDQ test. The operating system initialization segment includes a  
10 start-up control and a test of the CU. In the start-up control, different input values are tested on the control unit (e.g. a certain speed pattern of the wheels of a vehicle, as can typically occur at the input of an ABS control unit of the vehicle). The control unit carries out a regulation or control  
15 of the application based on the input values. The result of the simulated regulation or control is compared to corresponding setpoint values. When testing the CU, a defective MC is simulated, and the reaction of the CU to the defect is checked.

20 The online test has a command test and a core test, a RAM/ROM test, a test of the CU, and a replication test. In the replication test, double memory spaces are provided for certain safety-critical variables, and certain safety-critical  
25 calculations are carried out twice. The contents of the double memory spaces and the results of the double calculations are compared to one another. The redundant storing and the redundant calculation are carried out by a processor of the control unit. Furthermore, the online test has a plausibility  
30 check in which control signals or regulation signals determined by the MC are checked for plausibility. In the case of an ABS control unit, one can, for example, check whether the speed, the acceleration, or the deceleration are within



certain limits. Moreover, the values of the individual wheels of the vehicle must be in a certain relation to one another, which can also be checked. Finally, the online test has another operating system test and a test of the remaining monitoring units of the control unit.

A preferred exemplary embodiment of the present invention is explained in more detail in the light of the following drawings. The figures show:

Figure 1 shows a schematic overview of a block diagram of a control unit according to the present invention;  
Figure 2 shows a detailed overview of a block diagram of the control unit from Fig.1;  
Figure 3 shows a circuit configuration for a quiescent current measurement including a two-wire handshake;  
Figure 4 shows a timing diagram of the measuring run control for the quiescent current from Figure 3.

Figure 1 shows a schematic overview of a block diagram of a control unit according to the present invention. Reference numeral 1 designates the control unit according to the present invention in its entirety. Control unit 1 is used to control safety-critical applications, e.g. for anti-lock (braking) systems, for traction control systems, and/or for electronic stability programs. Control unit 1 has a microcomputer MC, a monitoring unit (CU, check unit), and peripheral circuits (IO, input/output). Microcomputer MC, monitoring unit CU, and peripheral circuits IC are connected in series via a serial synchronous databus 2. Via its data output line MC\_Dout, microcomputer MC transmits the data output signals through databus 2 to the bus users and simultaneously receives the data input signals via its data input line MC\_Din. Using the

signal SAM (sample), the bus users store the data received in their storage registers.

There are additional connecting lines between microcomputer MC and monitoring unit CU, namely a shared supply line VDD or alternatively, a plurality of supply lines VDD for a digital and analog supply of microcomputer MC. Finally, IDDQ handshake line IDDQ-HDSHK, which are used for controlling the quiescent current measurement (IDDQ measurement) of microcomputer MC, run between microcomputer MC and monitoring unit CU. So-called disabling paths 3 lead from monitoring unit CU to external warning lamps and/or relays to manipulate the safety-critical applications to be controlled, depending on whether monitoring unit CU detects an error of microcomputer MC. Peripheral circuits IO have connecting lines 4 to safety-critical application 5 to be controlled.

After control unit 1 is switched on, the quiescent current is measured to check the functionality of microcomputer MC. While control unit 1 is in operation, the functionality of microcomputer MC is checked in that it regularly receives test data records, and the corresponding second test data output signal of the MC is compared to an error-free first test data output signal calculated by monitoring unit CU.

Figure 2 shows a detailed overview of a block diagram of the control unit 1 from Figure 1. Monitoring unit CU includes a control system 6 of monitoring unit CU, a measuring run control 7 for the IDDQ measurement, an IDDQ measuring circuit 8, and a voltage supply 9. Control system 6 of monitoring unit CU includes a test data signal generator 10, a response generator 11, and a comparator 12. With the aid of test data signal generator 10, a test data input signal is applied to

microcomputer MC, and the microcomputer determines a second test data output signal as a function of the test data input signal and its own internal states. Response generator 11 processes the same test data input signal and forms a  
5 corresponding first test data output signal. In comparator 12, the first test data output signal of monitoring unit CU is compared to the second test data output signal of microcomputer MC. A trigger generator 13 determines the instant at which the second test data output signal of  
10 microcomputer MC is available at comparator 12, given an error-free, functioning microcomputer MC.

Control system 6 of monitoring unit CU further has a error counter 14, which counts an error, in the event that the  
5 second test data output signal of microcomputer MC is not consistent with the first test data output signal of monitoring unit CU, and/or in the event that the second test data output signal of microcomputer MC is available at comparator 12 at a different instant than the one determined  
20 by trigger generator 13.

Furthermore, control system 6 of monitoring unit CU has a test data register 17, which is used for transmitting and receiving test data.

25 Finally, control system 6 of monitoring unit CU also has an initialization circuit 15, which receives an initialization signal RST from voltage supply 9 after control unit 1 is switched on and subsequently synchronizes monitoring unit CU  
30 with microcomputer MC in that the monitoring unit waits for the first data transmission of the MC. Initialization circuit 15 subsequently activates test data signal generator 10 and error counter 14.

In test data signal generator 10, the test data input signals for microcomputer MC are generated in a virtually random order by a feedback shift register. With the aid of the Reed-Muller codes, the bit string for the corresponding first test data output signal is formed in response generator 11, for every test data input signal. This code is used to maintain a distance that is as great as possible in the space of numbers of the test data output signals (hamming distance) In comparator 12, the first test data output signal determined in response generator 11 is then compared to the actual second test data output signal of microcomputer MC.

The instant of the comparison is specified by trigger generator 13. This ensures that the time slices in microcomputer MC proceed correctly. Comparator 12 not only checks the second test data output signal of the MC for the correct data value but also to determine whether the test data output signal is transmitted within a specific timing window. If the value and instant of the second test data output signal of the MC are correct, error counter 14 is decremented, and the safety-critical application to be controlled is kept in an active state via a signal interface 16 in that external warning lights are switched off and the relays for triggering application 5 are activated.

In every cycle following this first cycle, the instant and value of the second test data output signal of the MC must be correct to prevent error counter 14 from responding immediately Error counter 14 has a plurality of response thresholds to prevent control unit 1 or application 5 from being switched off in the case of a singular disturbance and to enable microcomputer MC to check the disabling path. The first step blocks the valve output stages via signal EN and

switches off the voltage supply of the valves via valve relay VRA. The display of the warning lights SILA is delayed by one cycle, so that there is no display when testing the disabling path.

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If a test data input signal is responded to at the wrong instant or with an incorrect value, the same test data input signal is applied again to microcomputer MC until the instant and value are correct. If this does not occur within a predefined time period, monitoring unit CU switches off the control unit 1, and it can no longer be activated even by correct responses.

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After control unit 1 is switched on, the quiescent current is measured for a set number (typically 8 to 16) of selected instants of a test program. The communication between microcomputer MC and monitoring unit CU for measuring the quiescent current is carried out via the two handshake lines START and END. While the quiescent current is being measured, microcomputer MC stops clock generator CLK. Between monitoring unit CU and microcomputer MC are two separate voltage supply lines, VDD\_digital for supplying the digital component of microcomputer MC and VDD\_analog for supplying the analog component of microcomputer MC. The quiescent current is measured in voltage supply line VDD\_digital.

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The quiescent current measurement is enabled after the voltage supply is switched on via signal IDDQ\_EN of control system 6 of monitoring unit CU. The successful completion of the quiescent current measurement is signaled to control system 6 of monitoring unit CU by signal IDDQ\_FIN. Consequently, monitoring unit CU advances the test run in that initialization circuit 15 enables test data signal generator

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10 via a signal IDDQ\_OK.

Figure 3 shows a circuit configuration for measuring the quiescent current including a two-wire handshake. Figure 4 shows the timing diagram of measuring run control 7 for the quiescent current measurement from Figure 3. After control unit 1 is switched on, microcomputer MC starts its self-test. Part of this self-test is the quiescent current measurement. If the functional sequence in microcomputer MC reaches the quiescent current test, the START signal is activated. At instant T1, the quiescent current measurement is activated by signal\_Act. The output of comparator 12 for the quiescent current measurement is evaluated after time T2. If the value is acceptable, microcomputer MC is activated again by the END signal. If the value is outside of a limiting value, the measurement is repeated. The number of repetitions is preset. If repeating the measurement also does not produce a correct response, the measurement is discontinued, and monitoring unit CU does not switch on microcomputer MC but remains in a fail-safe mode. When all quiescent current measurements are completed, signal IDDQ\_FIN is set to HIGH. Consequently, control system 6 of monitoring unit CU resets signal IDDQ\_EN from HIGH to LOW.